Simultaneous Chandra-NuSTAR view of the Bursting Pulsar

George Younes*, Kouveliotou, C., Kennea, J., Grefenstette, B., Miller, J., Tomsick, J., Harrison, F. et al.

*USRA at NASA-MSFC

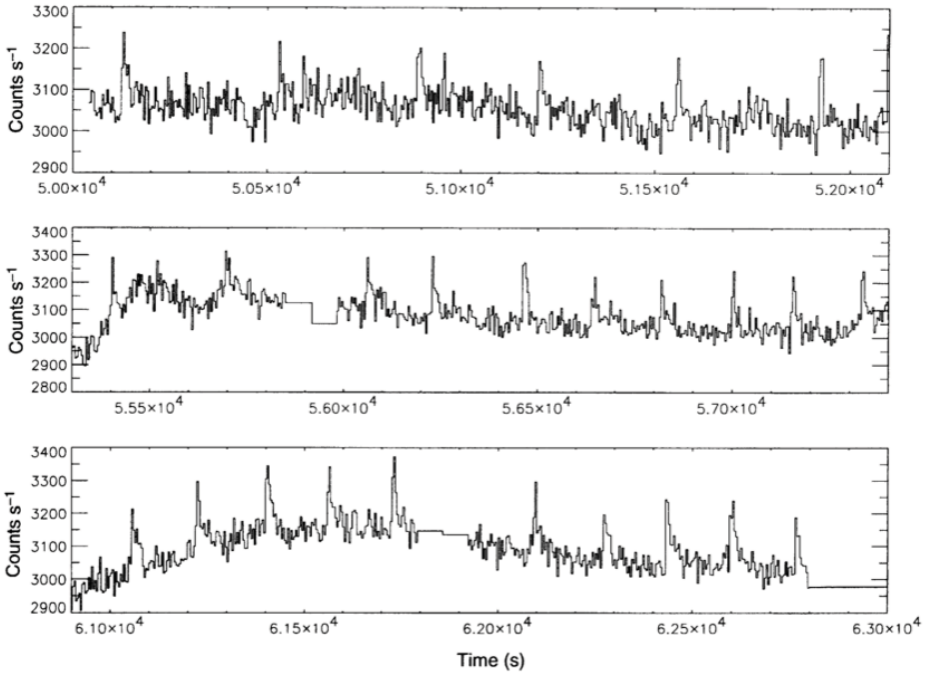
The Bursting Pulsar: GRO J1744-28

- Discovered in 1996 with BATSE, emitting an average of 40 hard X-ray bursts/day, lasting ~10s each (Fishman et al. 1996, Kouveliotou et al. 1996)

- Bursts are reminiscent of Type II bursts from the rapid burster — markedly different from the thermal type I bursts (This makes it 2 known sources to emit type II bursts, Lewin et al. 1996)

- LMXB in a nearly circular orbit: Porb=11.8 days, P=0.467 s, B < 6×10^{11} G (from spin-up rate, Finger et al. 1996)

- 2 known outbursts (1996 and 1997, ~100 days long each),
  - Timing properties very well-known
  - Lacks good spectral study
  - At peak of both outbursts, persistent, $L_{\rm X} > L_{\rm EDD}$ bursts $L_{\rm X} >> L_{\rm EDD}$

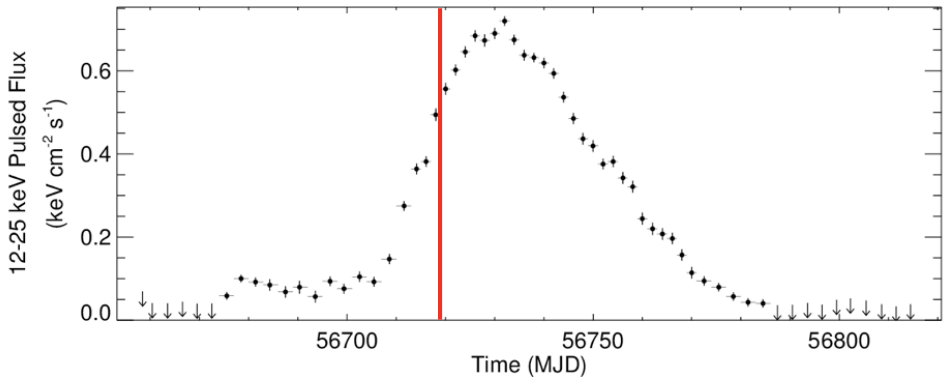


25-60 keV, Kouveliotou et al. 1996

The come back

- Nearly 18 years later, 2014 January 18, MAXI/GSC detection of what later turned out to be the Bursting Pulsar (Negoro et al. 2014b)
- Swift, FERMI/GBM, and MAXI detection of persistent and/or hard X-rays bursts for nearly 100 days.
- Campaign to observe the source with all available imaging high-energy instruments, including NuSTAR and Chandra, for multiple observations.
- 2014 March 03, Simultaneous NuSTAR/Chandra-HETG observation for 10 ks.

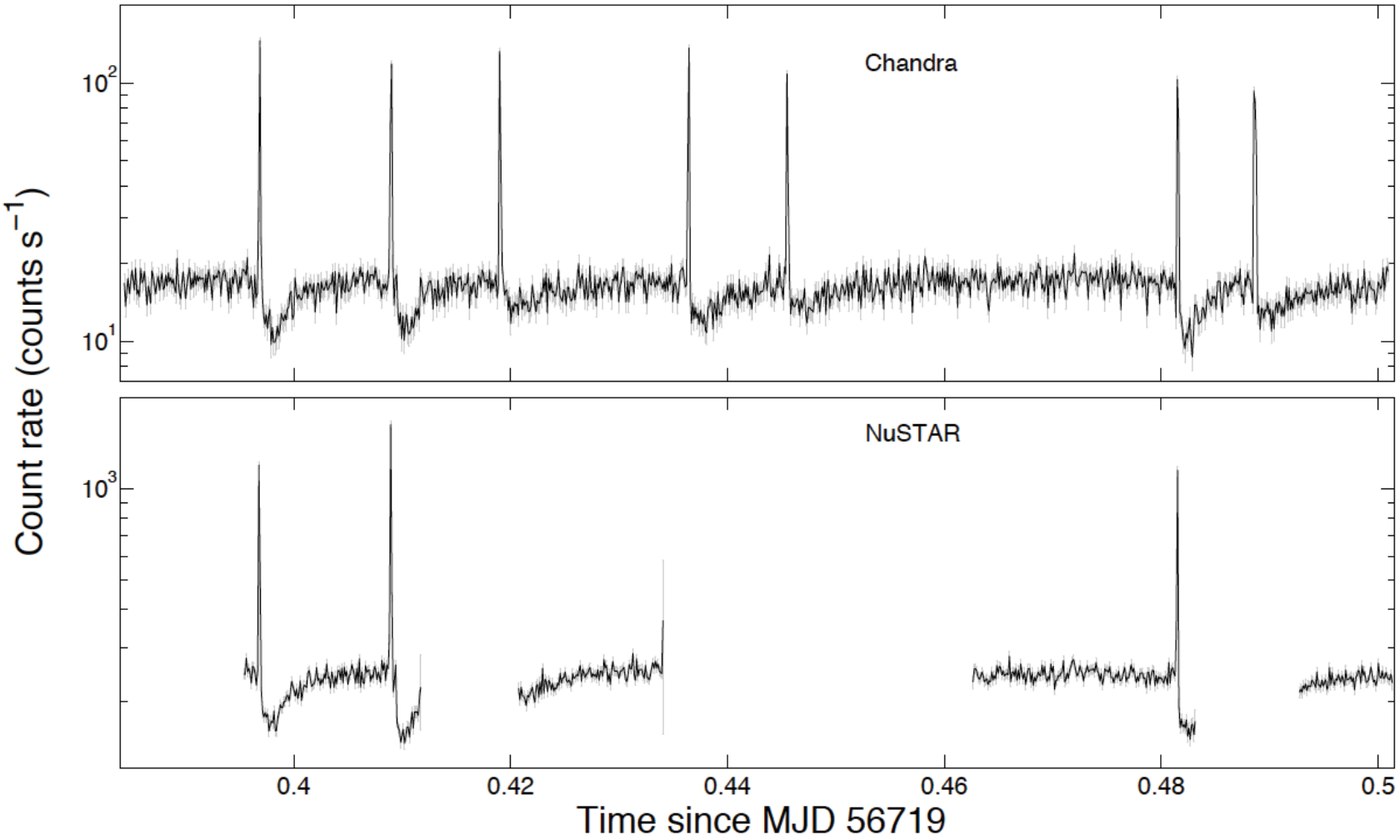
GRO J1744-28, January17 to May 09, 2014



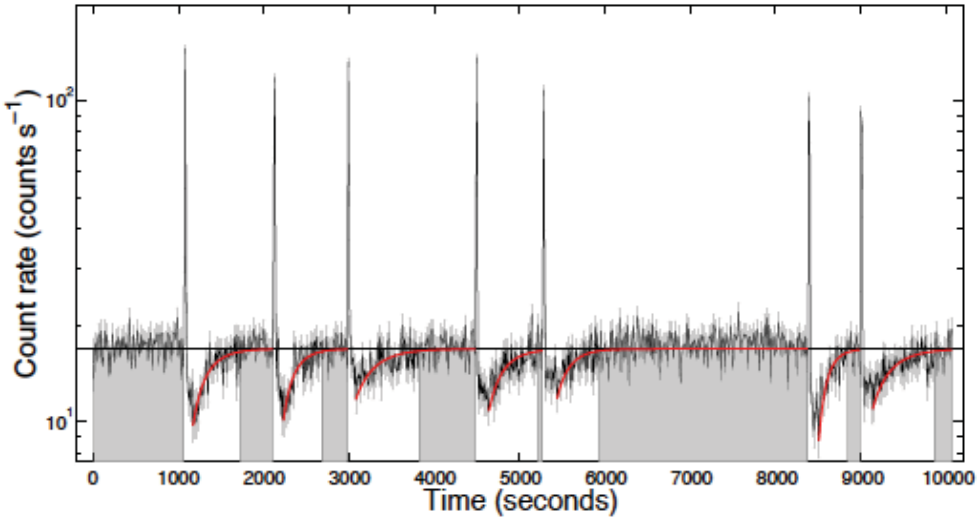
FERMI/GBM, Finger et al. 2014

Time of NuSTAR/Chandra observation, L_X~L_Edd

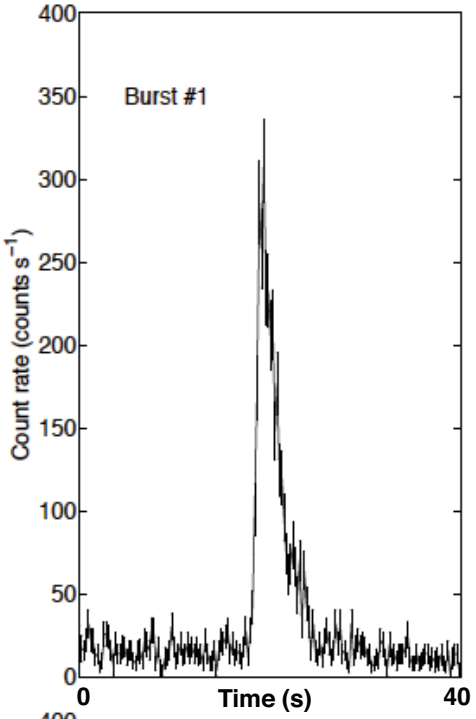
Simultaneous NuSTAR/Chandra LC



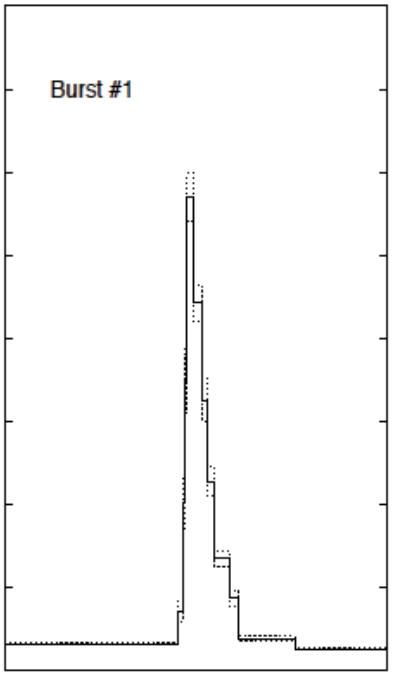
Chandra observation

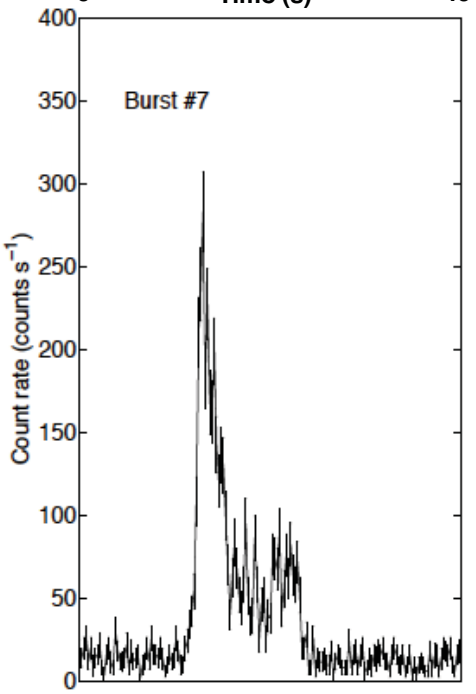


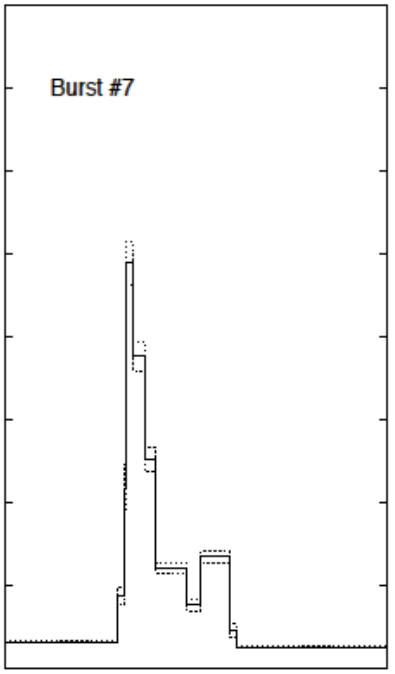
Raw LC, 0.5 s res.



BB representation







Temporal properties

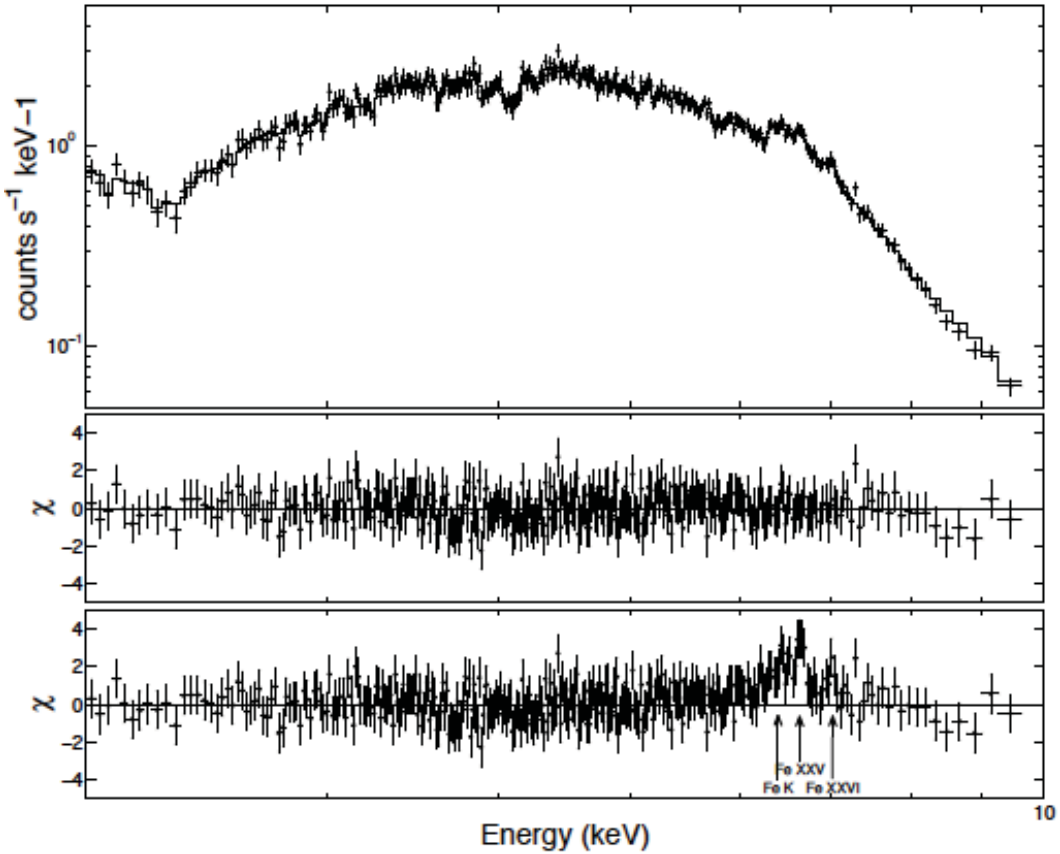
Burst duration ~12 s, except for 1

Dip recovery, $\tau \approx 190 \pm 40$ s

Flux at dip minimum 20% of persistent level

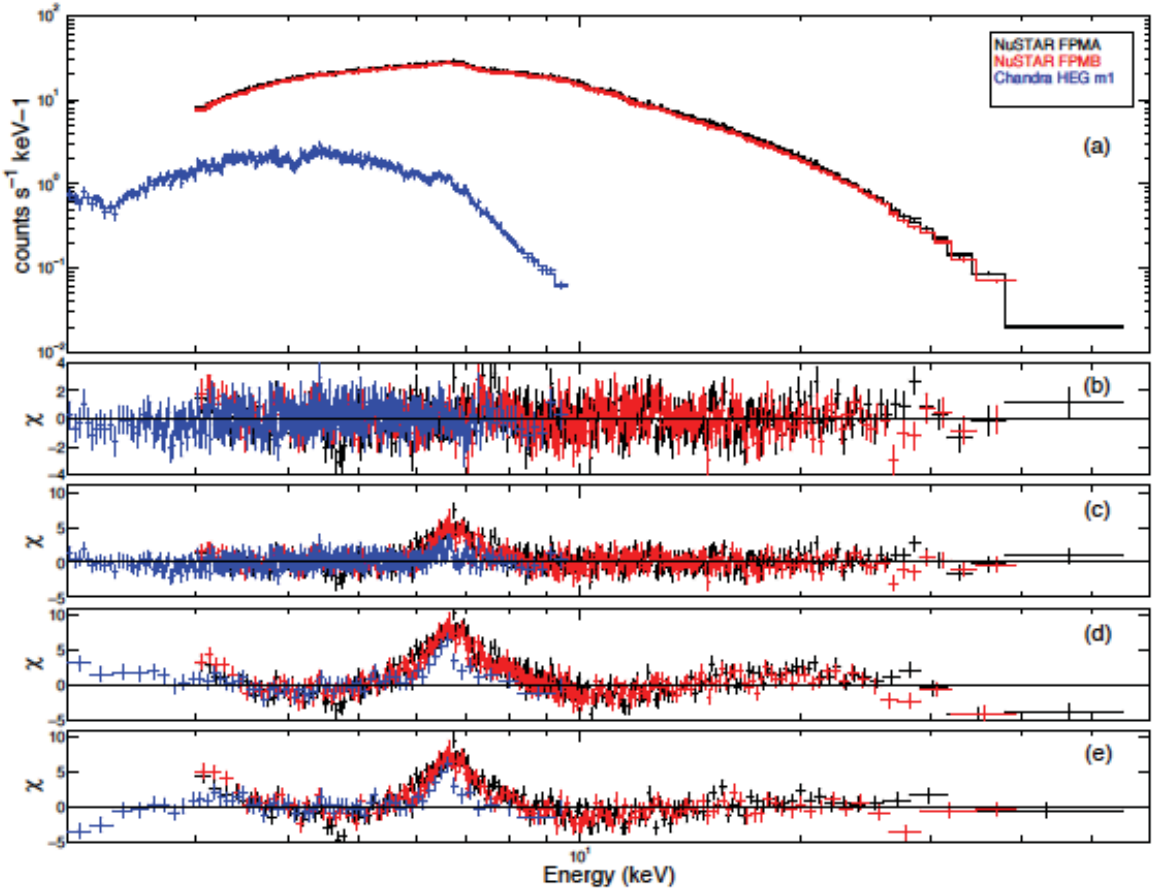
Spectral analysis: Chandra

Persistent+dips spectrum



- Absorbed PL gives a good fit to the Chandra only spectrum, $N_{\rm H} = 6.4 \times 10^{22}\ {\rm cm}^{-2}, \Gamma = 1.0$
- Narrow features appear at energies consistent with (quasi-) neutral Fe, and highly ionized ones
- Persistent and dips intervals have identical spectra
- Features disappear in burst spectra, but same continuum

NuSTAR+Chandra: spectral fits



Persistent emission best fit model:

- Absorbed (BB+cutoffPL), and a 10 keV absorption feature
- 3 narrow Gaussian lines

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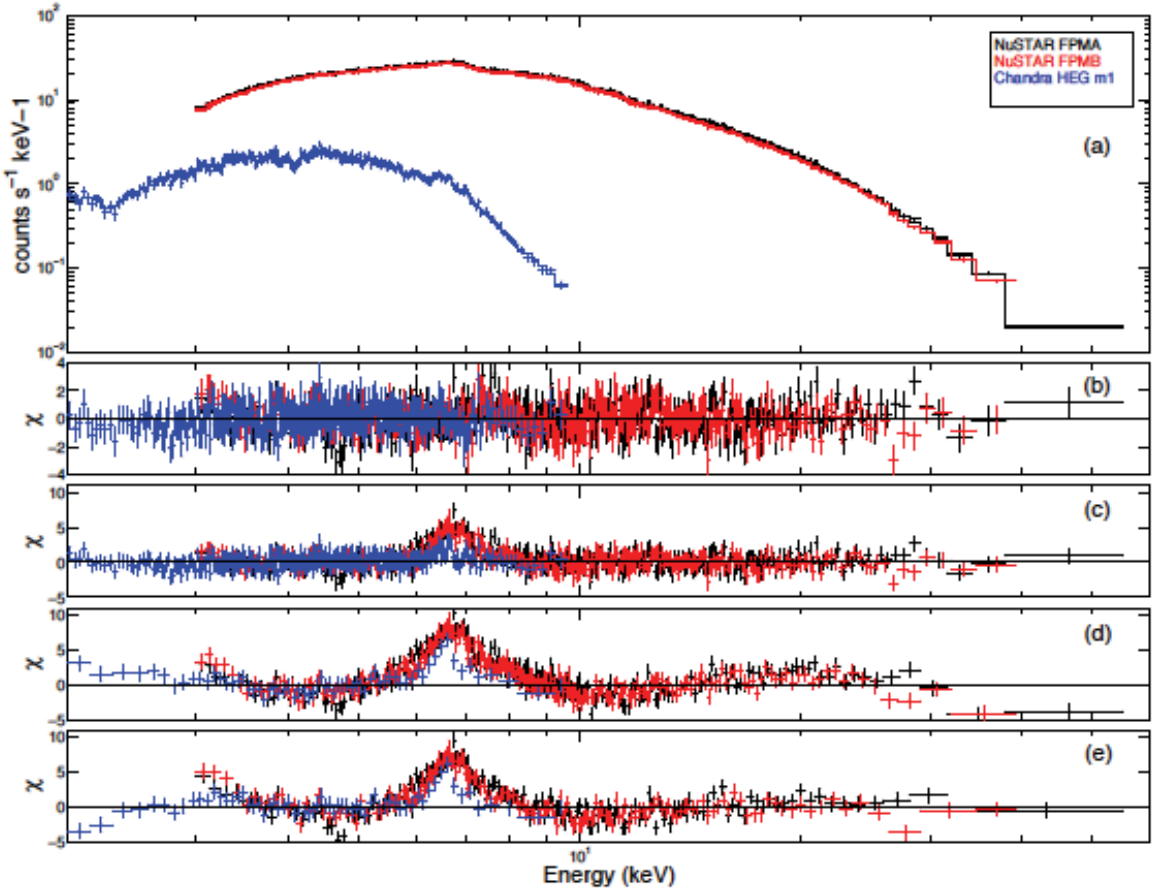

- Heavily absorbed, $N_{\rm H} = 6.5 \times 10^{22}$ cm^{-2}

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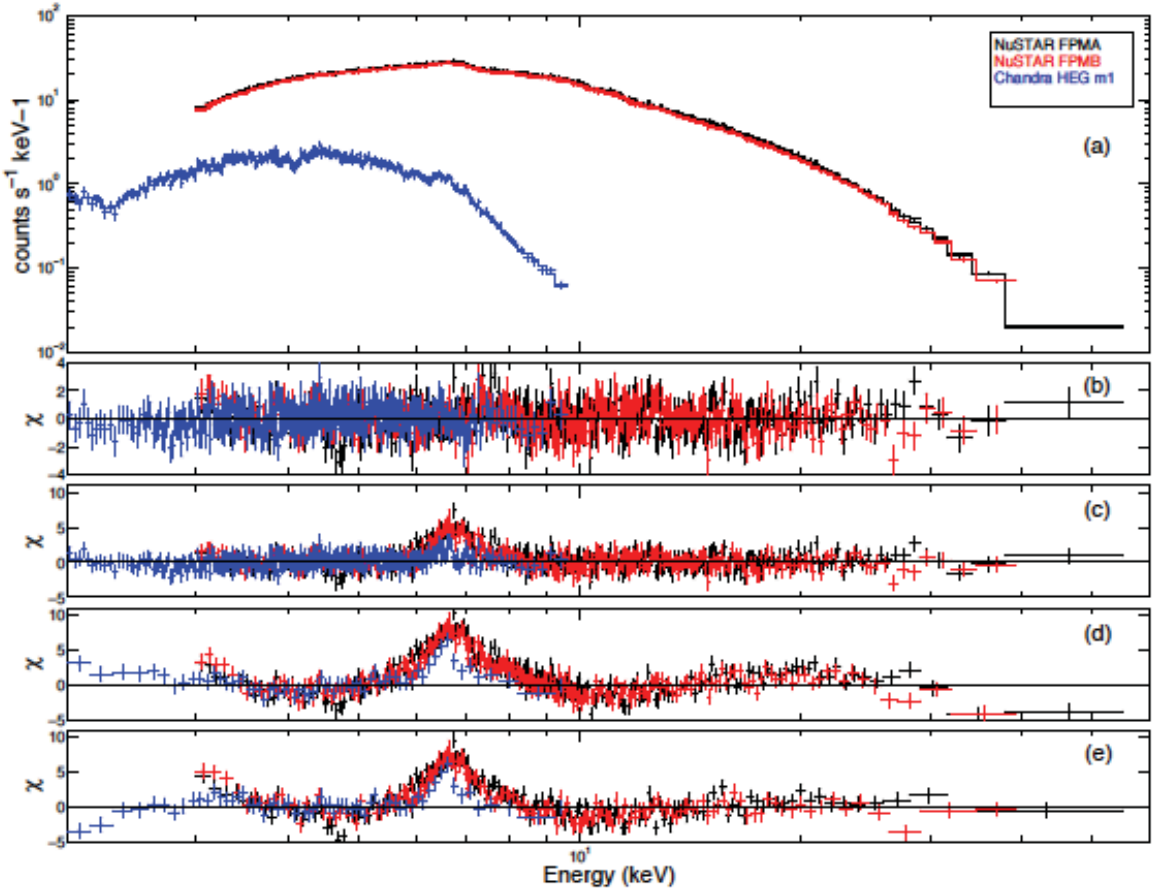
NuSTAR+Chandra: spectral fits



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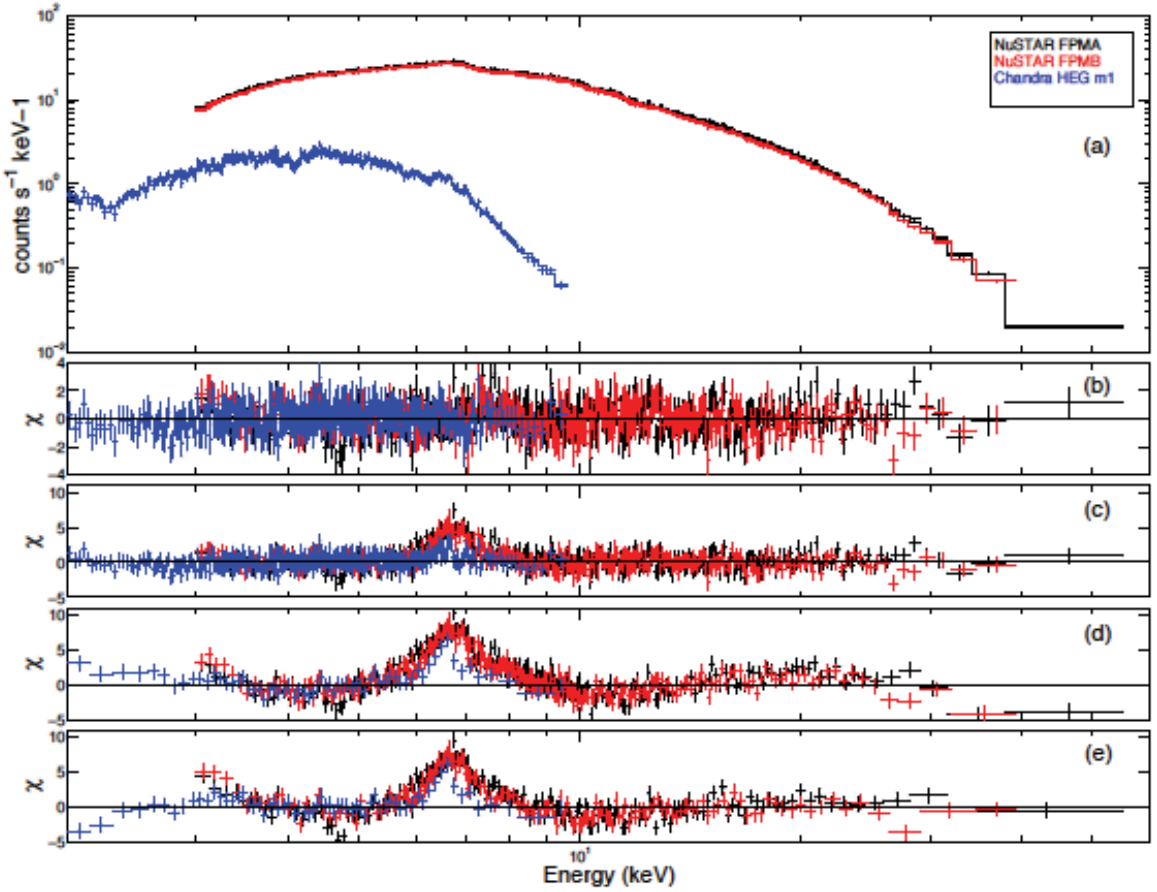

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- Lines: $E1 = 6.44$ keV, $EW1 \sim 80$ eV, $E1 = 6.65$ keV, $EW1 \sim 40$ eV, $E1 = 6.99$ keV, $EW1 \sim 25$ eV

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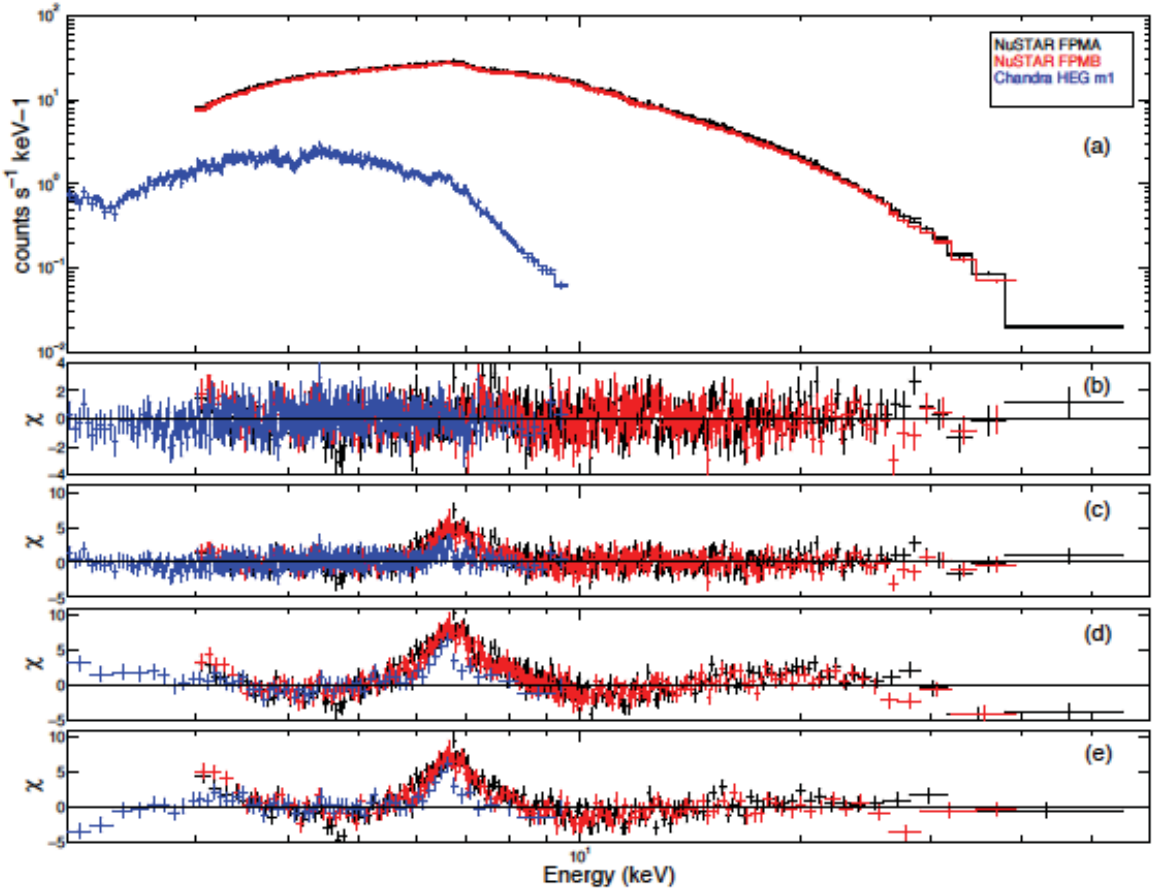

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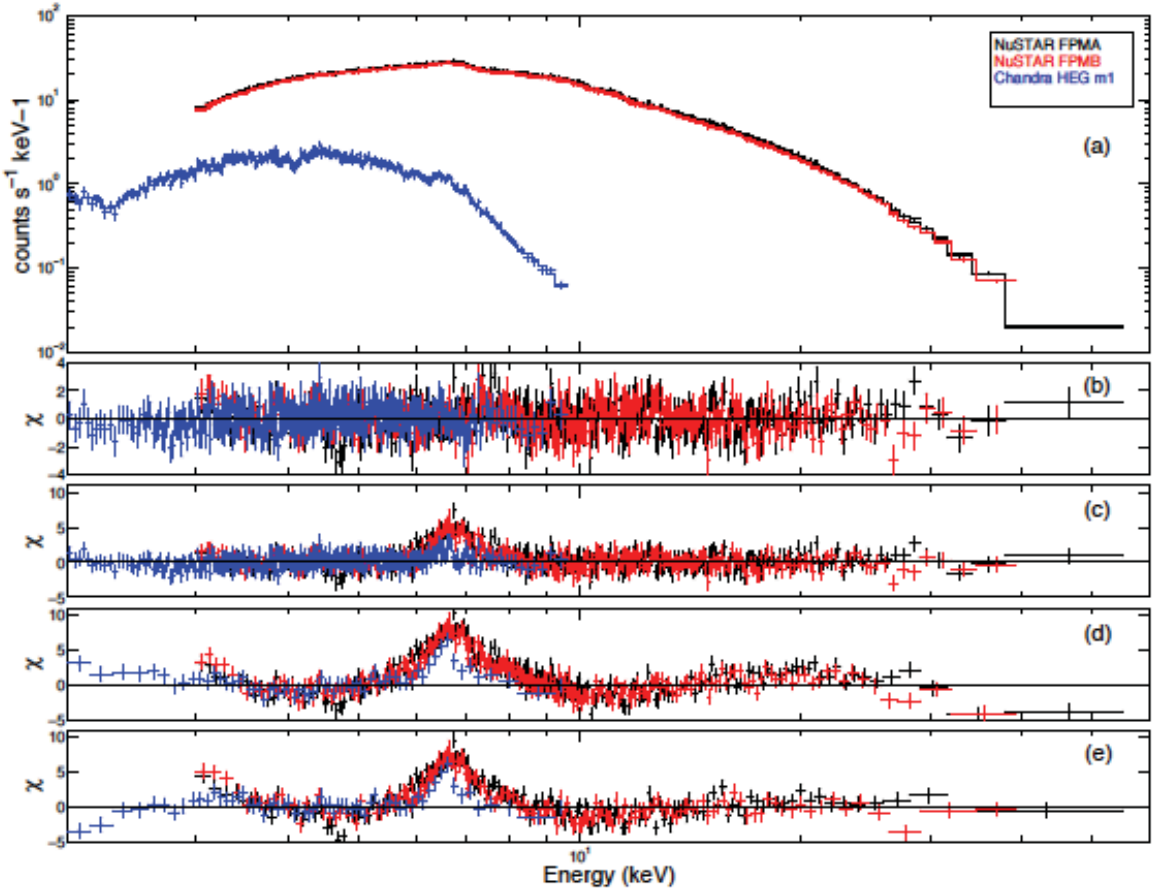

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- cutoffPL, $\Gamma = 0.0, E_{\rm cut} = 7.0$ keV, $F = 2.49 \times 10^{-8}$ erg s^{-1} cm^{-2}

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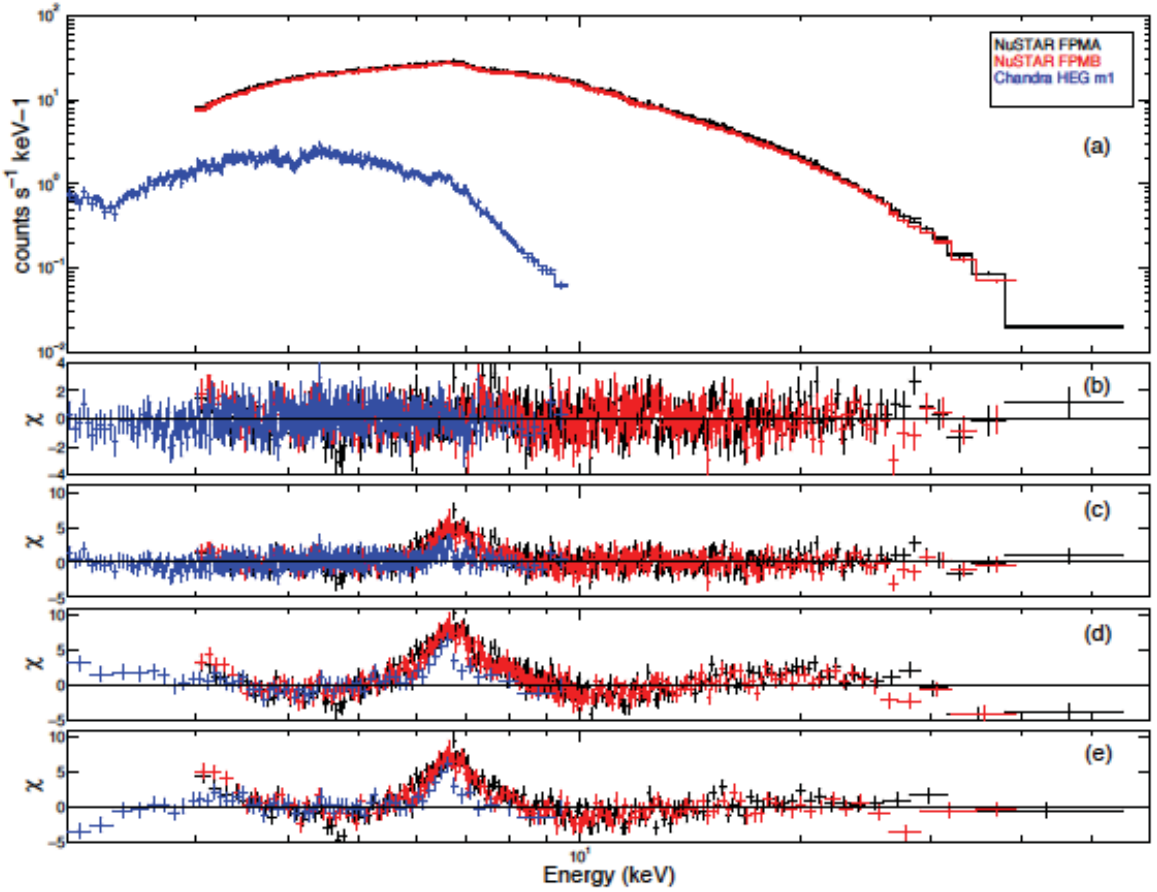

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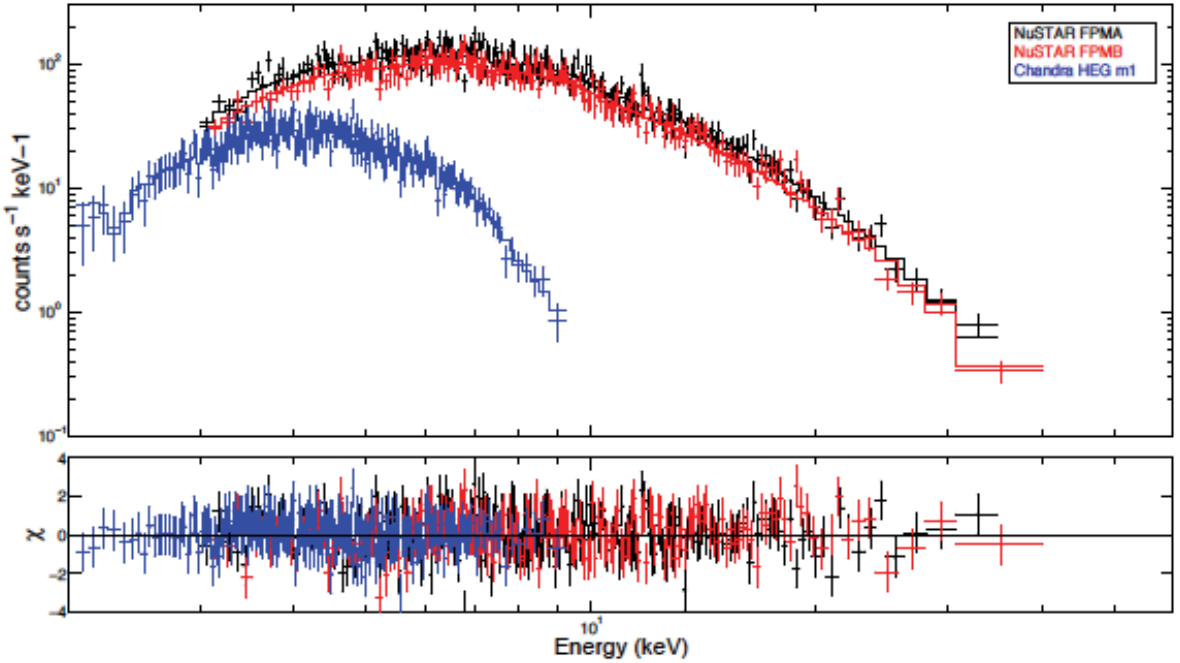
- *All spectral parameters consistent between persistent and dip emission, except cutoffPL flux: 12% decrease on average during dips, 20% at minimum*

Spectral analysis: NuSTAR+Chandra



Burst emission best fit model:

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- Statistically speaking, no need for a BB component. No need for lines either

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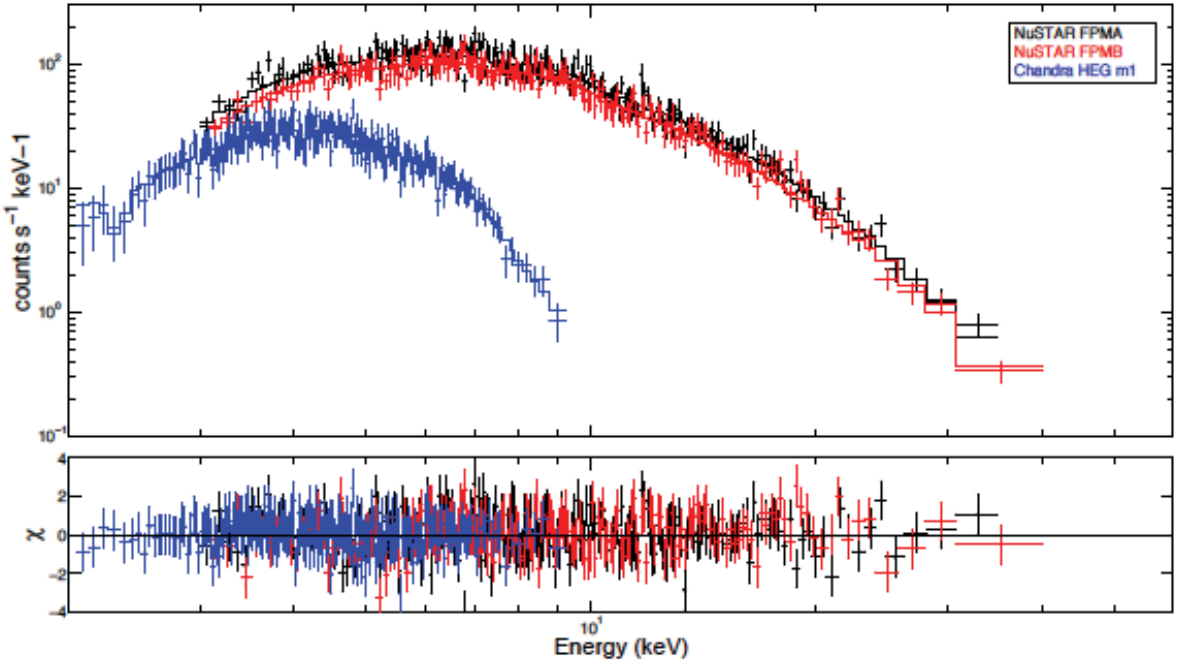

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Compared to persistent and dips spectra:

- Absorption is lower, $N_{\rm H} = 4.7 \times 10^{22}\ {\rm cm}^{-2}$

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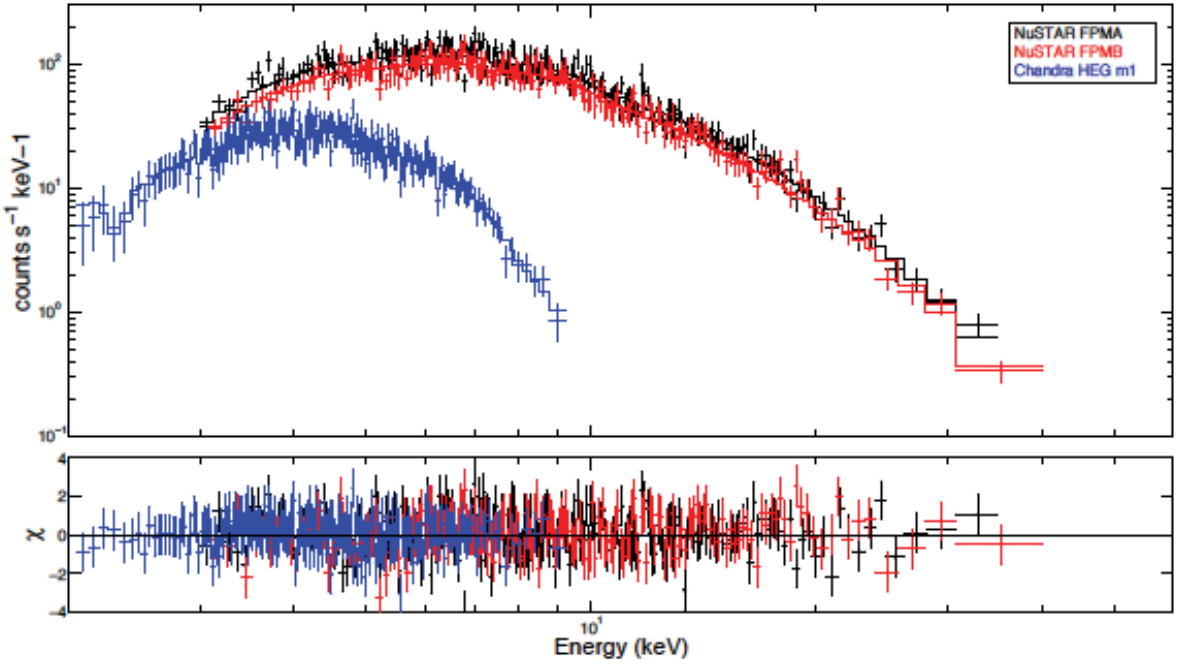

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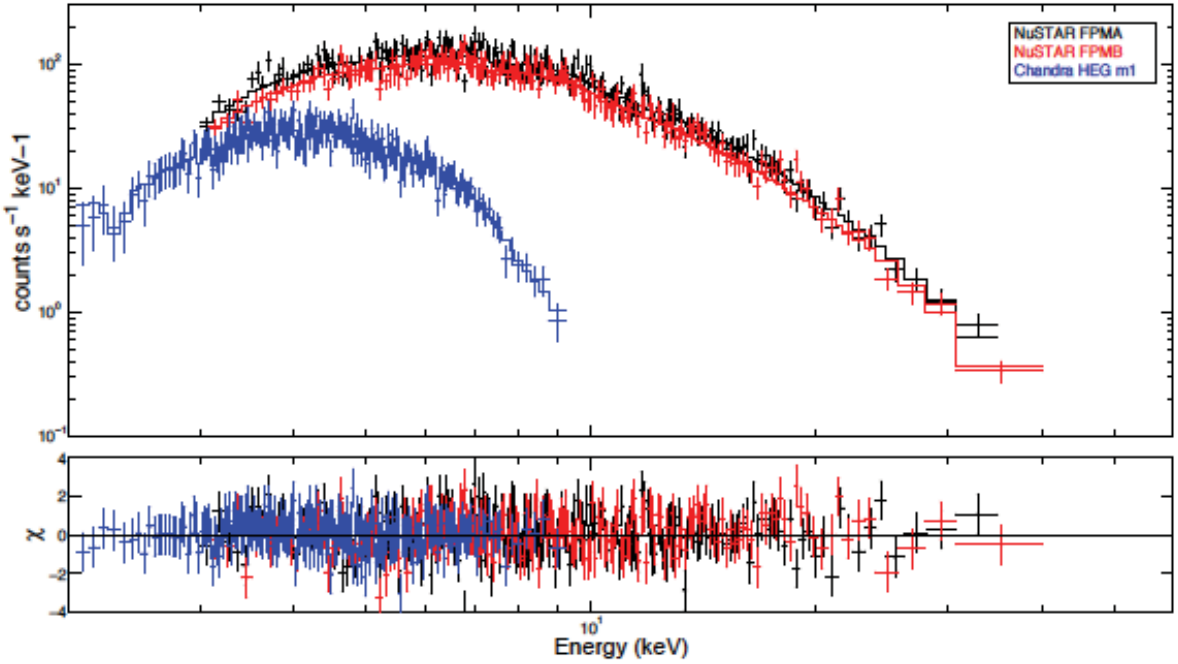

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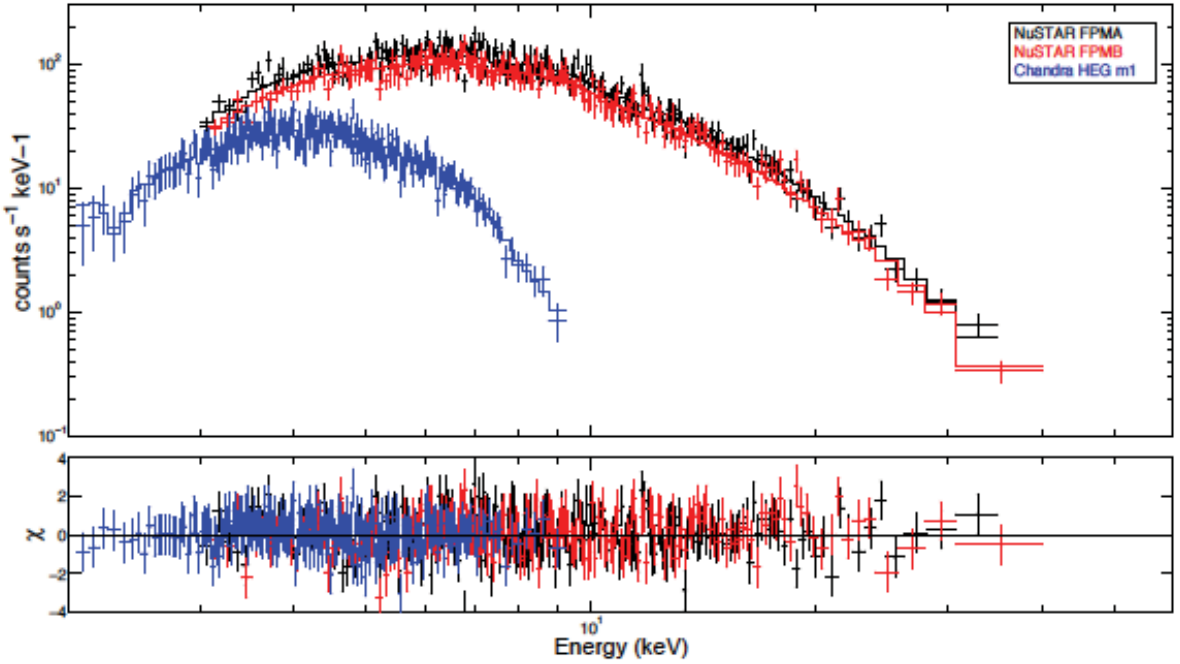

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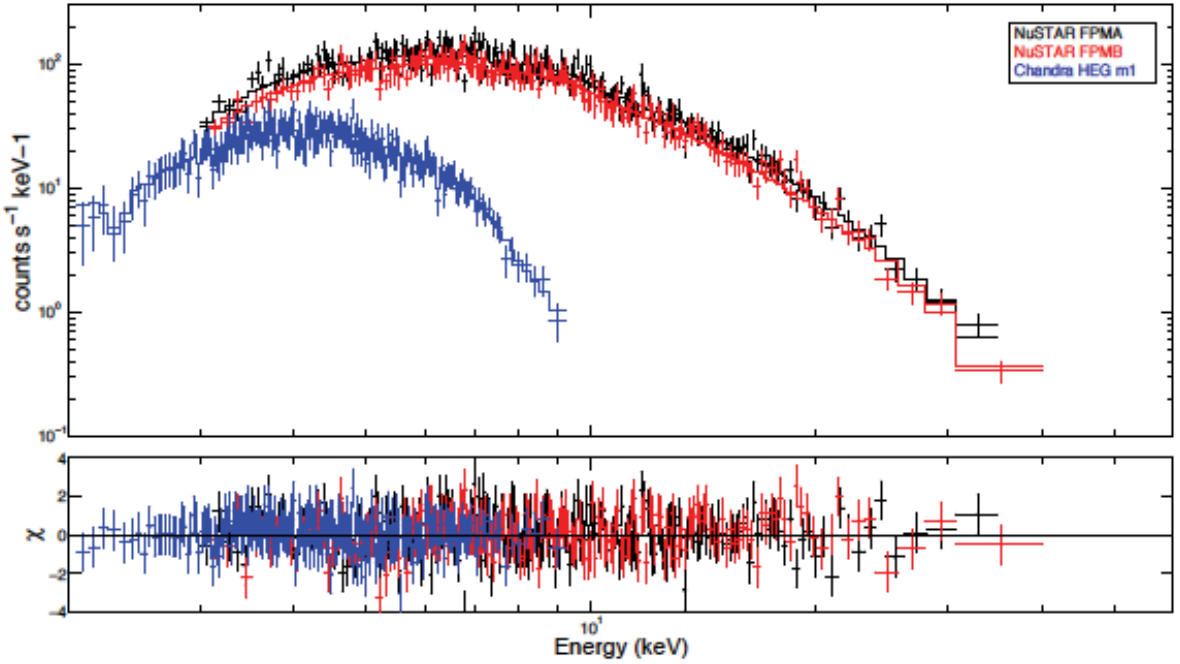

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- cutoffPL and 10 keV feature consistent with persistent and dips spectra

If absorption value frozen to persistent spectrum, BB temperature and flux during bursts consistent with persistent and dips

Conclusion

- Bursts properties during this outburst seem to be similar to the first 2
- Same continuum emission mechanism for all intervals; persistent, dips, and bursts
- No BB component during bursts, despite a one order of magnitude increase in non-thermal emission. No lines either. — emission is anisotropic during bursts.
- From hard X-ray flux and the fact that the source is spinning-up, dipole B-field is $B < 3.5 \times 10^{11}$ G